Adapting COTS Technology for Big Physics Applications

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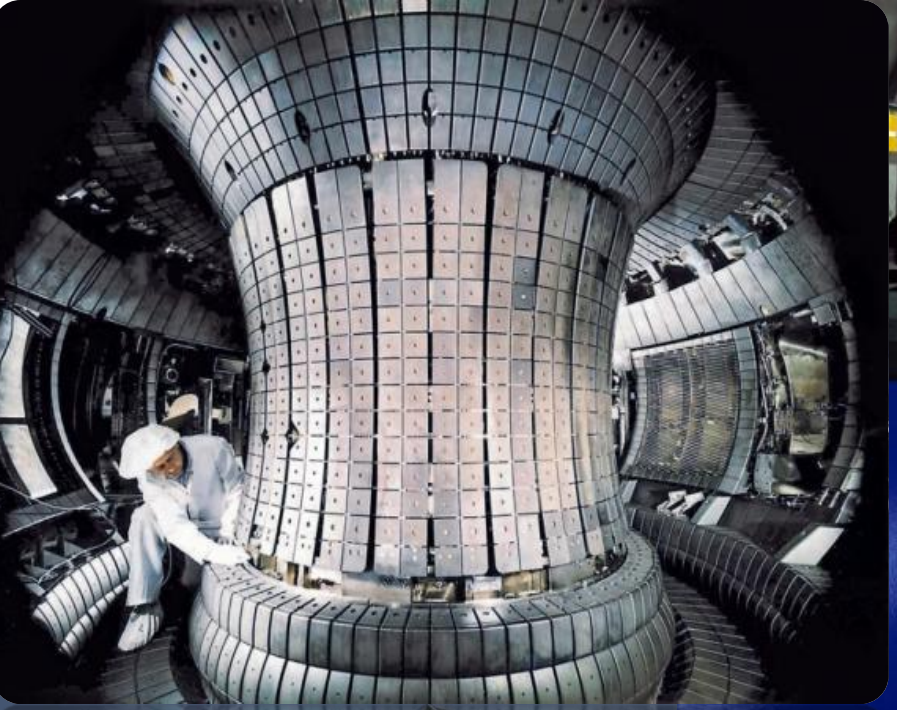
NATIONAL INSTRUMENTS

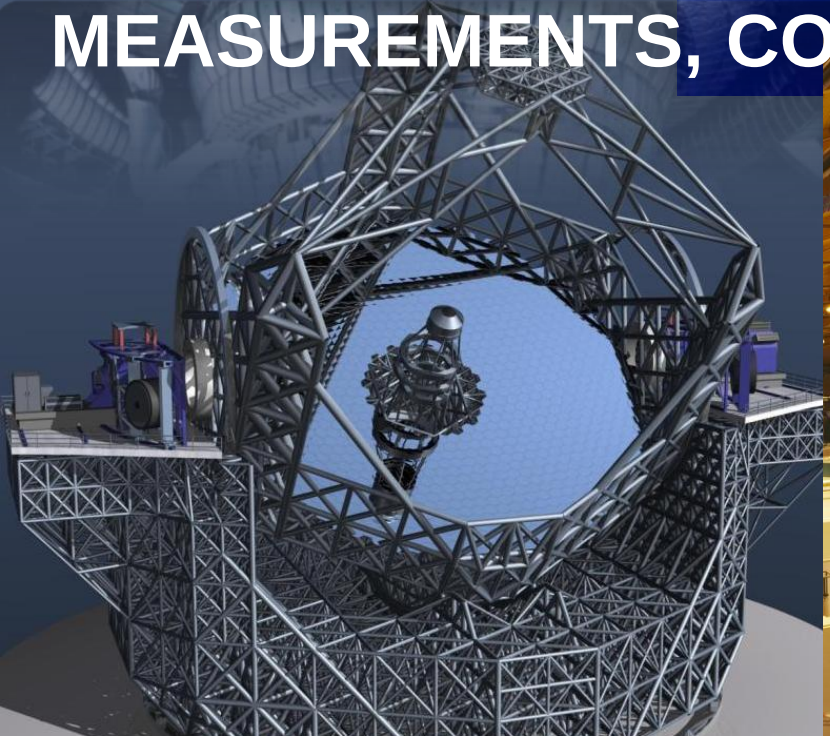
Agenda –

- Involvement in Big Physics
- Special Big Physics Application Requirements
  - Linux
  - EPICS
  - Radiation and Magnetic Field Testing
  - RASM
  - Lifecycle Management
  - Global Services

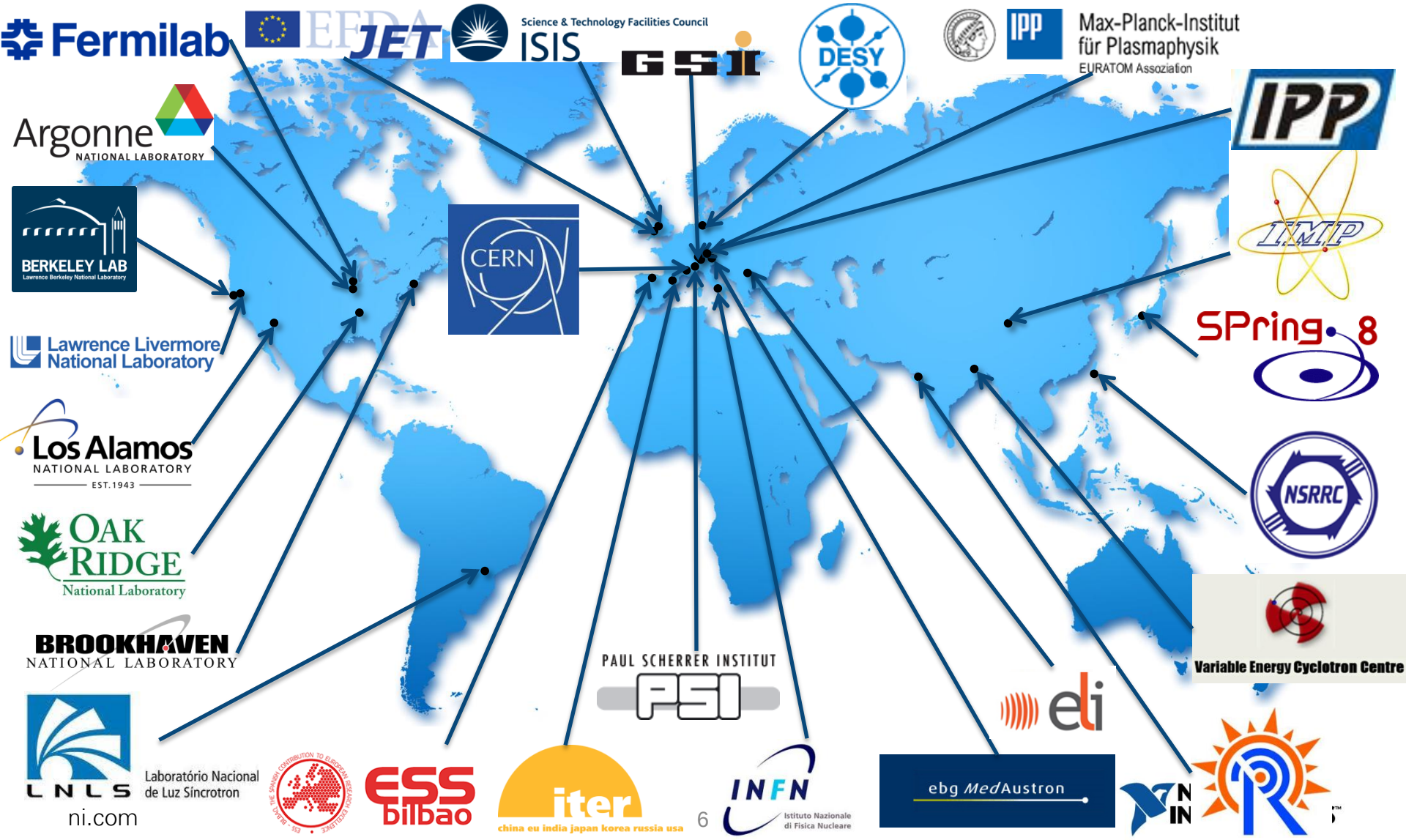
Diversity of Applications – Multitude of Benefits



MEASUREMENTS, CONTROL AND DIAGNOSTICS



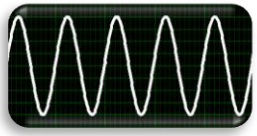
Worldwide Customers



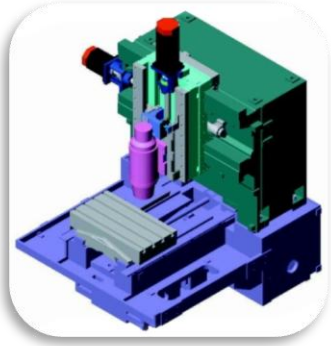
BP Application Requirements
Measurement, Control and Diagnostics

HMI

Logging, Database

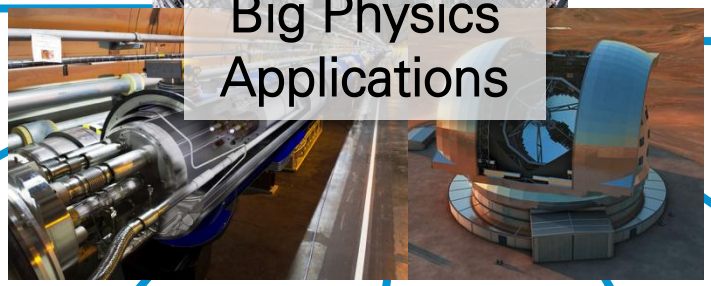


Sensors and Signal Conditioning

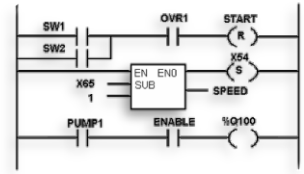


Mechanical Design

Networking



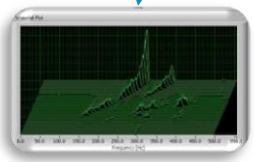
Big Physics Applications



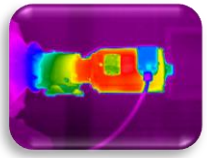
Discrete and Sequential Logic

Embedded System Design

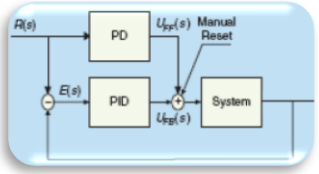
Motors and Actuators



Machine Condition Monitoring



Machine Vision



Motion Control Design

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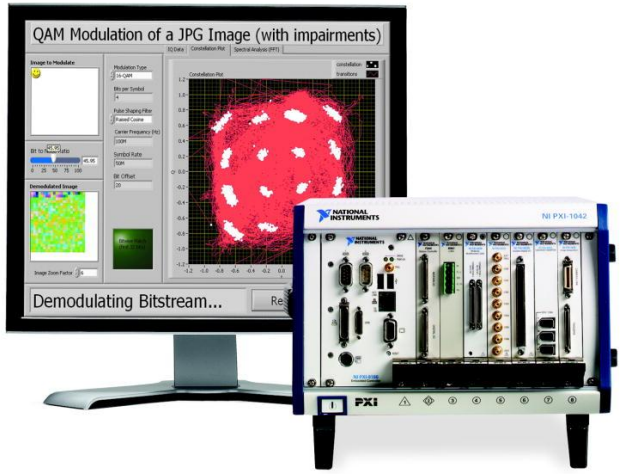
Comprehensive Product Portfolio: High Performance



More than 1,500 PXI Products from More than 70 Vendors

DAQ and Control:

- Multifunction I/O
- FPGA/Reconfigurable I/O
- Digital I/O
- Analog Input/Output
- Vision and Motion
- Counter/Timers

Instruments:

- Oscilloscopes
- Digital Waveform Generator/Analyzers
- Digital Multimeters
- Signal Generators
- Switching
- RF Signal Generation and Analysis

Interfaces:

- GPIB, USB, LAN
- SCSI + Enet
- Boundary Scan/JTAG
- CAN + DeviceNet
- RS232/RS485
- VXI/VME

Comprehensive Product Portfolio: Low cost, robust and compact

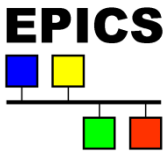
- Analog Input
  - Up to 250 kS/s, simultaneous sampling
  - 4, 8, 16, and 32-ch options
  - Built-in signal condition for sensors
    - Strain gages, accelerometers, thermocouples, RTDs
  - Up to ± 60 V, ±20 mA
  - 12, 16 and 24-bit resolution
  - Available ch-to-ch isolation
- Analog Output
  - Up to100 kS/s simultaneous updating
  - Up to 16-ch per module
  - ±10 V, ±20 mA
  - Isolation

- **Digital I/O**
  - Up to 10 MHz timing
  - Counter/timer, PWM
  - 8 and 32-channel options
  - 5V/TTL, 12/24/48 V logic levels
- **Specialty**
  - 2-port CAN modules
  - Brushed DC servo motor drive
- **Third Party Modules**
  - LIN, Profibus, WLAN 802.11, MIL-1553, ARINC-429, GPS, and more

BP Application Special Requirements

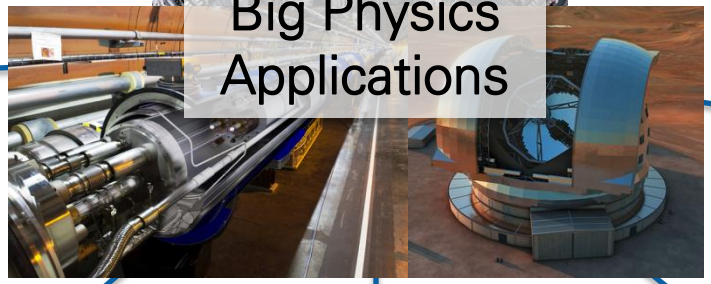
Linux Support

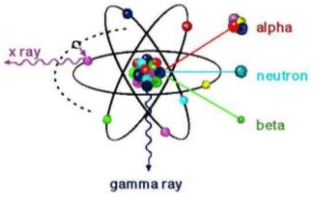
RASM



EPICS Support

Lifecycle Management





Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

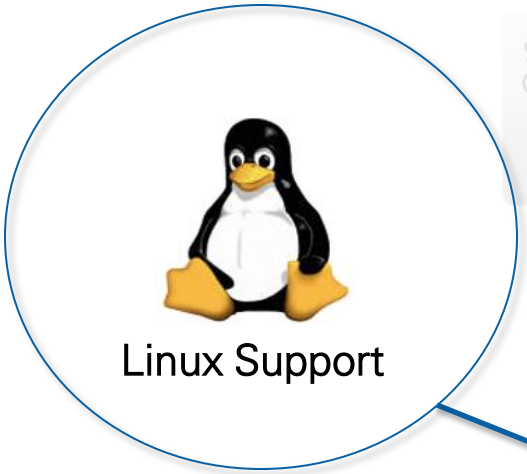
Environmental: ROHS, ChinaROHS, WEEE

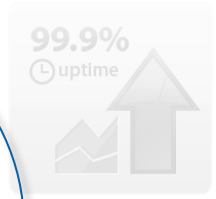
Global Technical Support

Global Calibration And Repair

NATIONAL INSTRUMENTS

Linux Support





RASM

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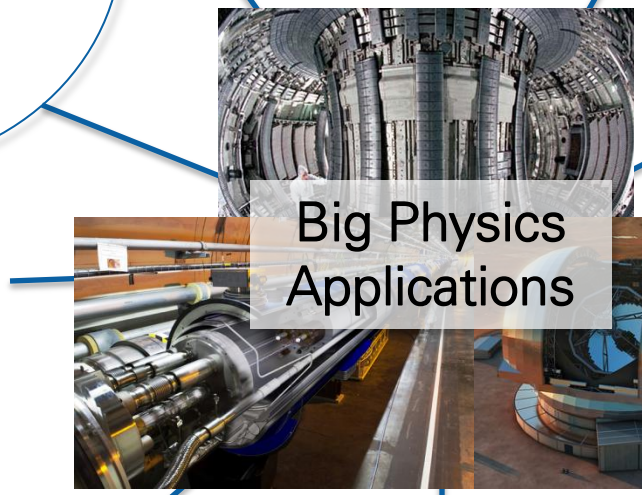

Radiation and Magnetic Field Testing

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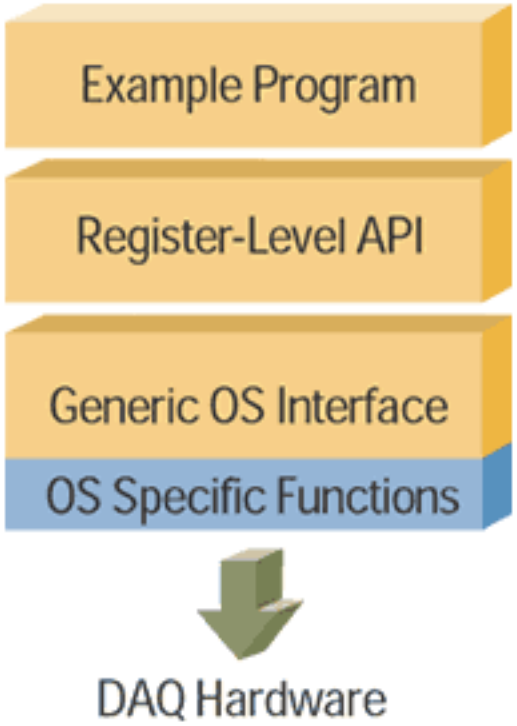
Global Technical Support

Global Calibration And Repair

NI MHDDK

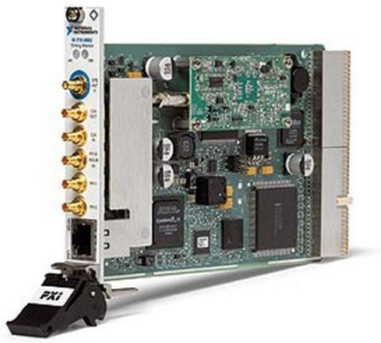
- Measurement Hardware Driver Development Kit
- Register-level programming for Data Acquisition Devices
- Multiple OS support
- Driver developed entirely by the customer
- Source code only, very small footprint



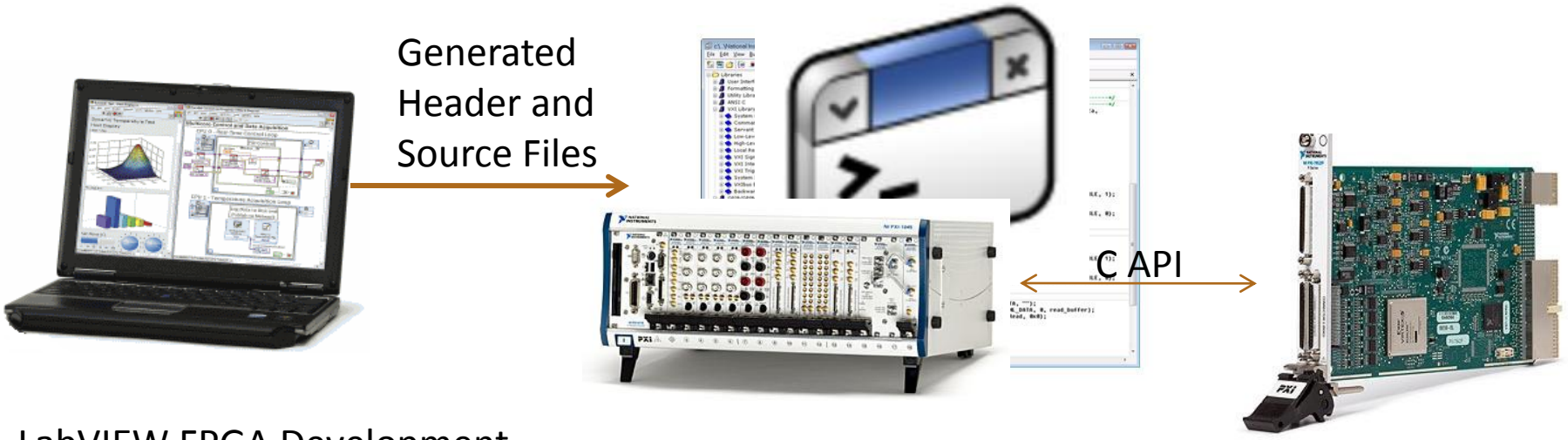
MHDDK Based Driver Available

- PXIe 6368: Multifunction Data Acquisition
- PXI 6259: Multifunction Data Acquisition
- PXI 6528: HV Digital I/O
- PXI 6682: Timing
- PXI 6683: Timing (Available Q1, 2014)



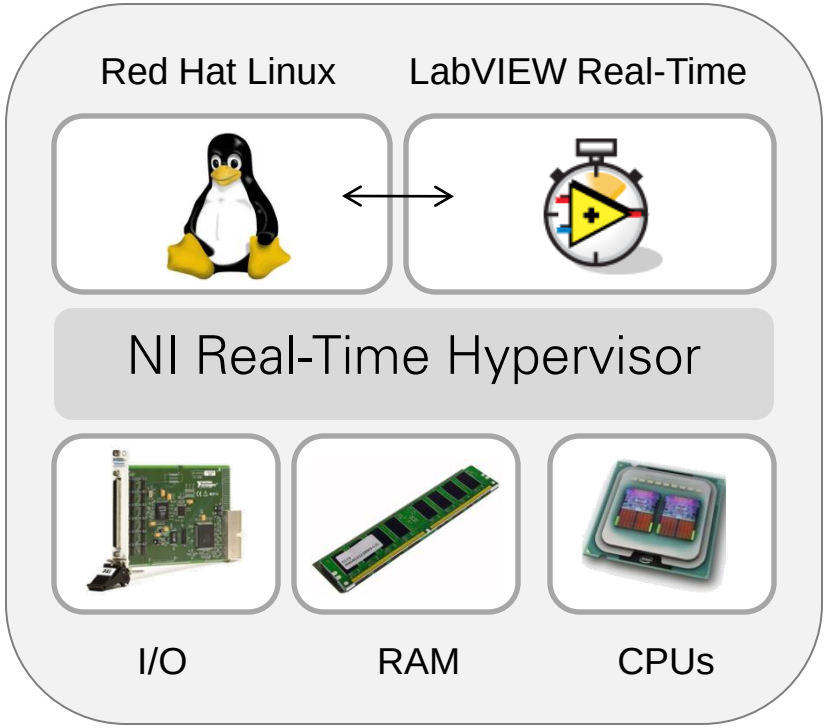


Deploying RIO Devices Under Linux



1. Develop LabVIEW FPGA VI, compile bitfile, and generate C API.
2. Develop and build C/C++ application with generated C API.
3. Deploy built application and bitfile to Linux target, and run.

NI Real-Time Hypervisor for Linux



- Combine real-time processing with Linux applications
- Connect to any I/O devices supported by LabVIEW Real-Time or Linux
- Communicate between OSs with high throughput shared memory

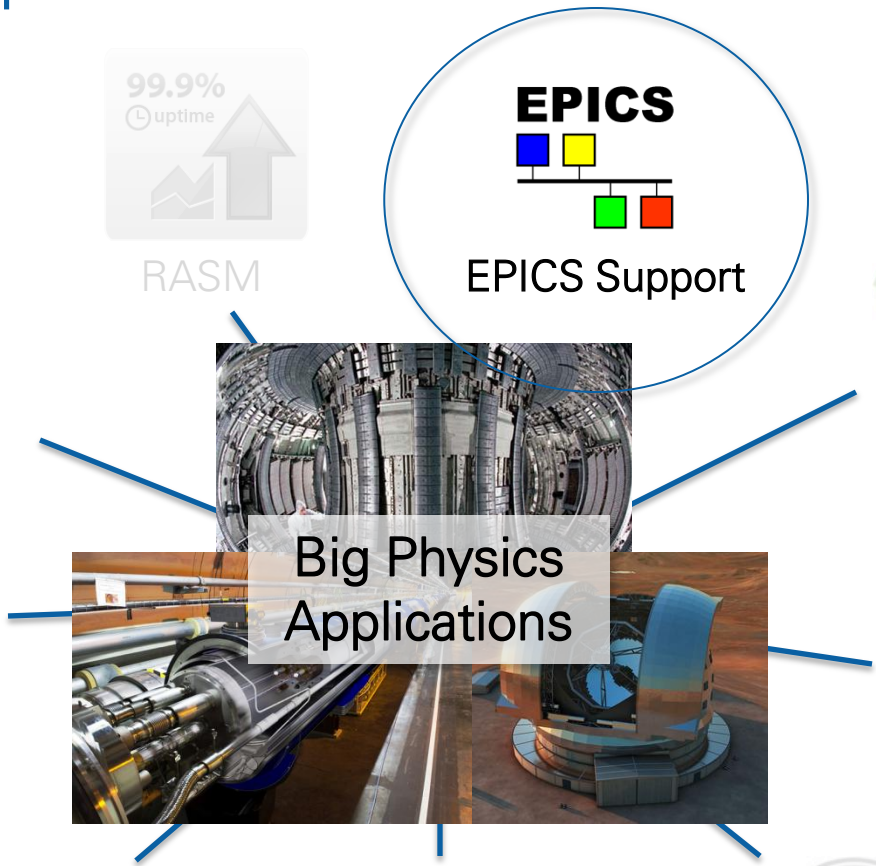
ESS Ion Source

- Controlling and monitoring a ion source (ISHN) at ESS
- PXI and FPGA running LabVIEW interfacing with Linux operator interface through EPICS on real-time controller

Linux Integration - Summary

Hardware	Customer Custom Driver Development	NI Custom Open Source Driver	Platform Integrated
Measurement HW	MHDDK	ITER	DAQmx Linux, Hypervisor
RIO	FPGA interface C API	ITER	API, Hypervisor

EPICS Support



RASM

Linux Support

Lifecycle Management

Radiation and Magnetic Field Testing

Safety : EMI, UL, CE, SIL

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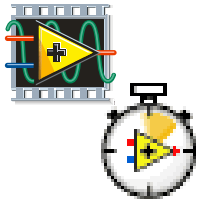
Global Technical Support

Global Calibration And Repair

EPICS Integration



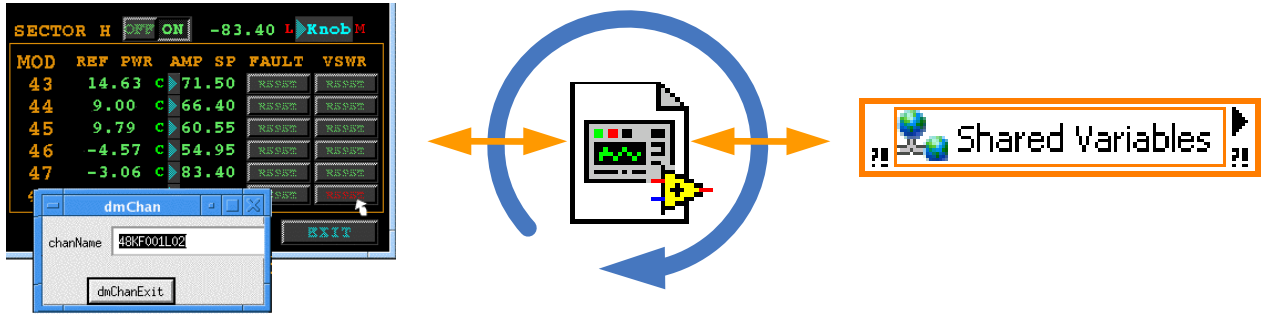
LabVIEW	I/O Server	EPICS CA Client or Server

LabVIEW RT on cRIO	Shared Memory	EPICS IOC on VxWorks
LabVIEW RT on PXI	Hypervisor Shared Memory	EPICS IOC on Linux

PXI (No LabVIEW)	Linux Driver Device Support	EPICS IOC on Linux

Concept of EPICS in LabVIEW

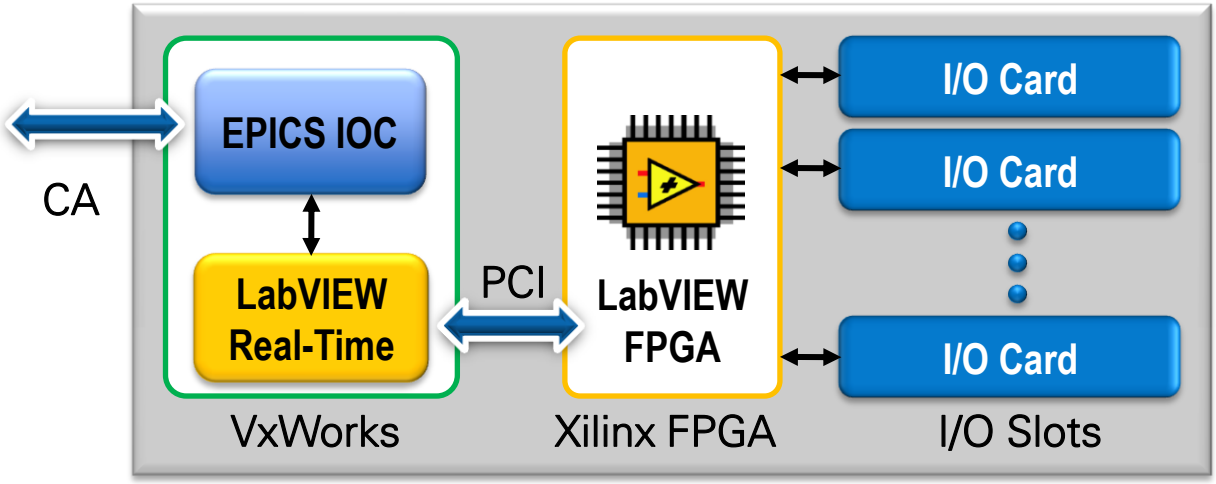
- EPICS CA Server and EPICS CA Client implemented as plug-ins to the I/O Server
- Interface in LabVIEW is implemented via the Shared Variable Engine



Process Variables (PVs) I/O Server Shared Variables

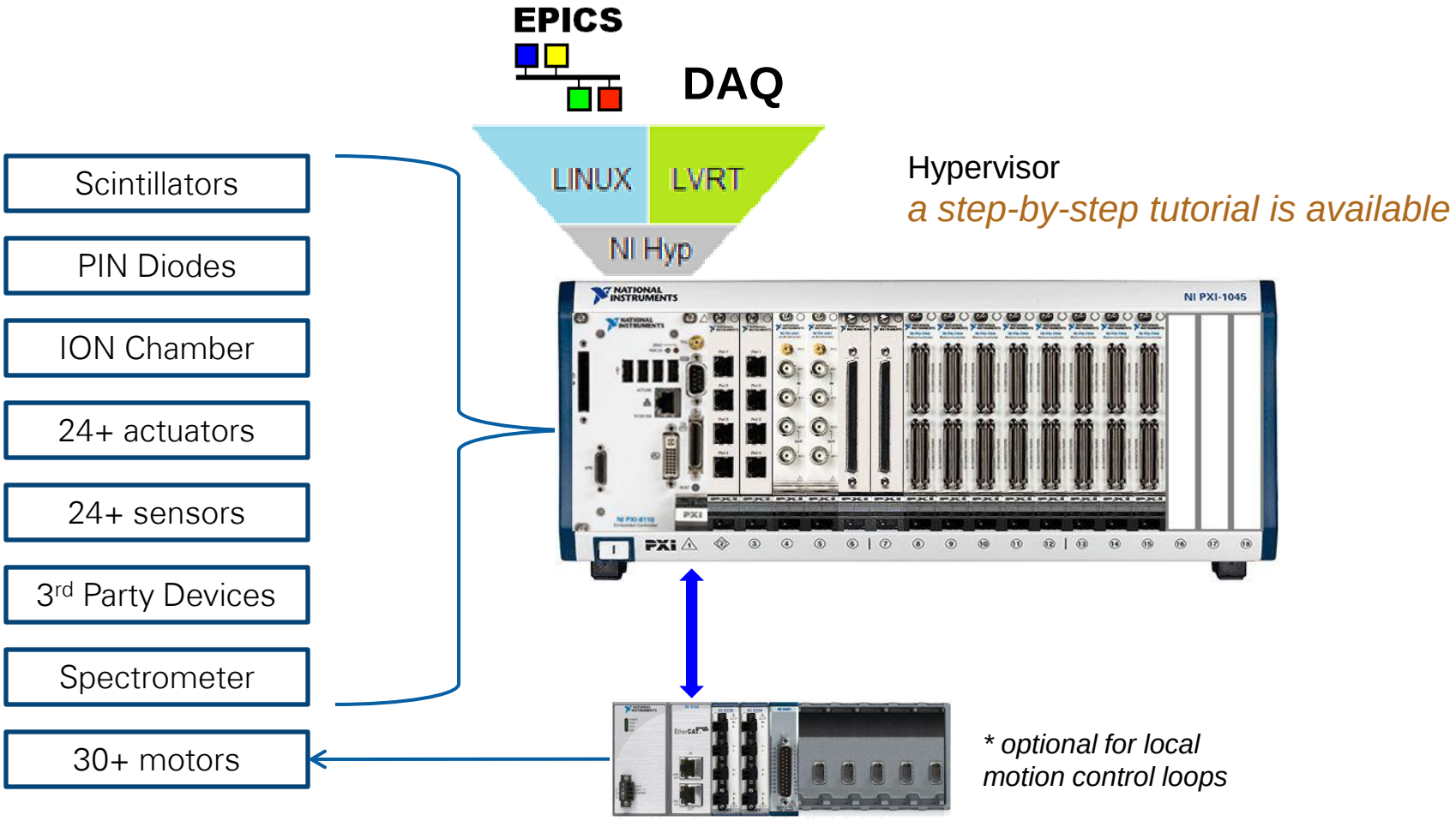
Embedding EPICS IOC on CompactRIO

- EPICS IOC and LabVIEW Real-Time running simultaneously
- Take advantage of FPGA platform with CompactRIO



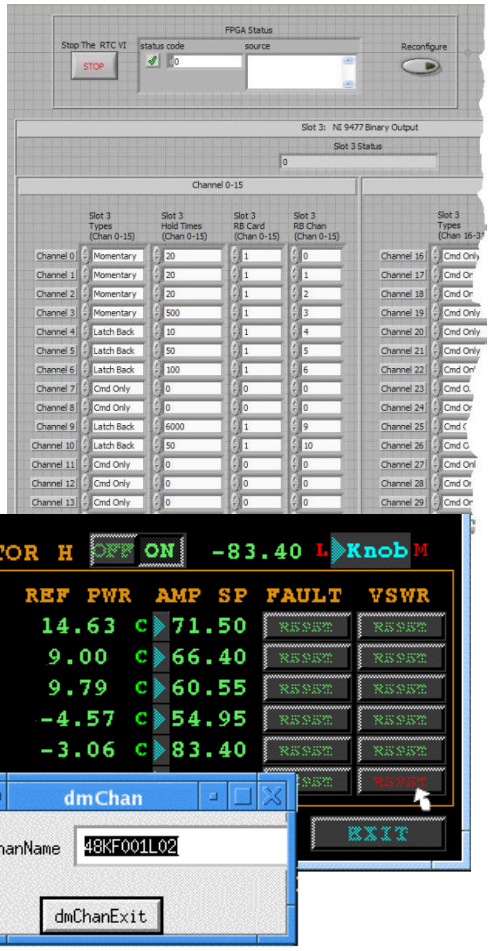
CompactRIO Architecture

Beam Line Proposed Automation

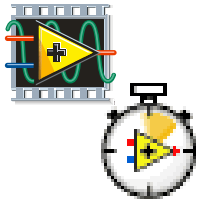


Los Alamos LANSCE

- Migration to a cRIO with embedded EPICS
  - 12 binary outputs
  - 36 binary inputs
  - 12 analog inputs
  - 5 stepper motor channels
- Full IOC functionality allows access to all record fields and EPICS utilities
- Maximum flexibility for partitioning the problem
  - LabVIEW for beam diagnostic
  - EPICS for industrial control



EPICS Integration Summary



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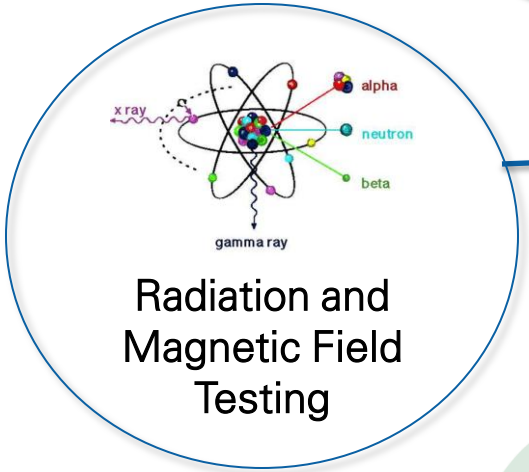
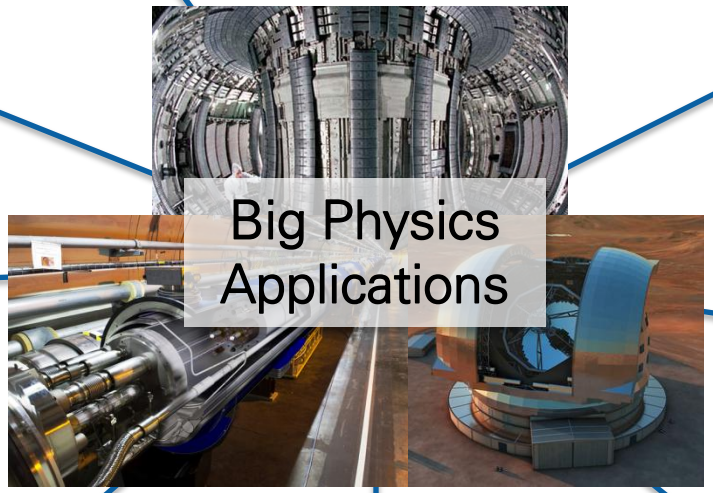
Radiation and Magnetic Field Testing



Radiation and Magnetic Field Testing



Big Physics Applications

Linux Support

RASM

EPICS Support

Lifecycle Management

Safety : EMI, UL, CE, SIL

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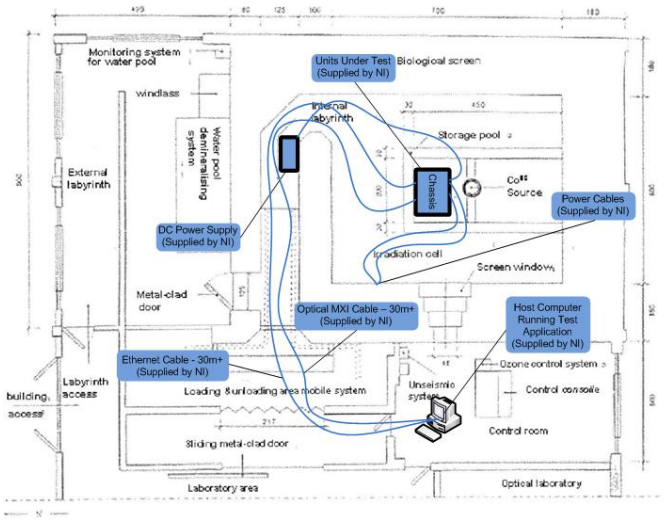
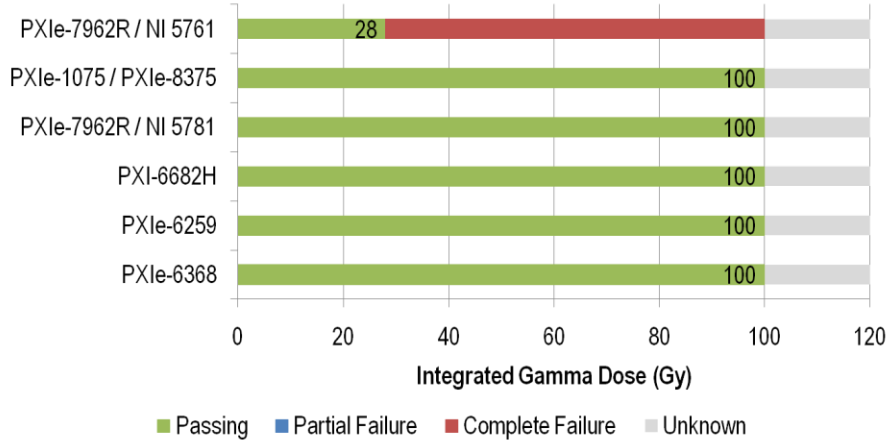
Global Technical Support

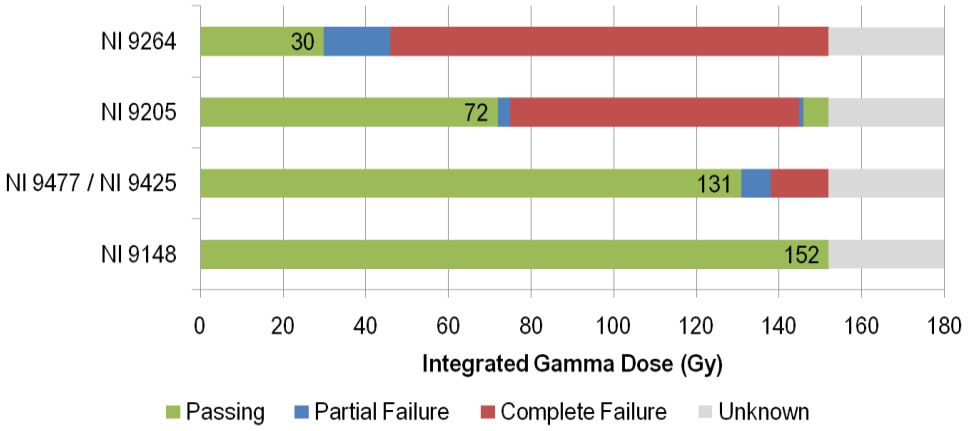
Global Calibration And Repair

Calliope Gamma Research Lab at ENEA Casaccia



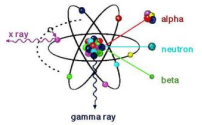
PXIe and cRIO Gamma Testing





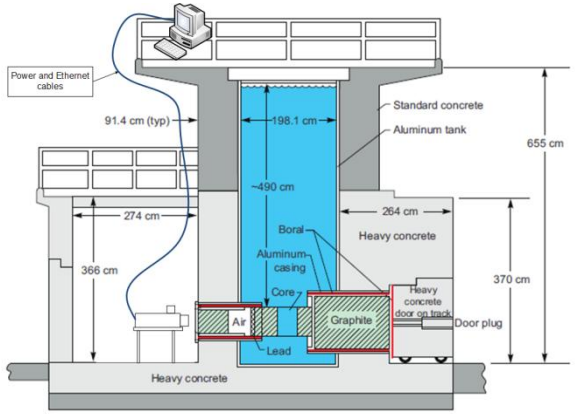
- Cumulative effects are evident in the gamma testing
- Most (1 PXI / 1cRIO) failed devices exceeded expected failure dose of 50Gy
- More than half of the devices exceeded the maximum expected failure dose of 100 Gy

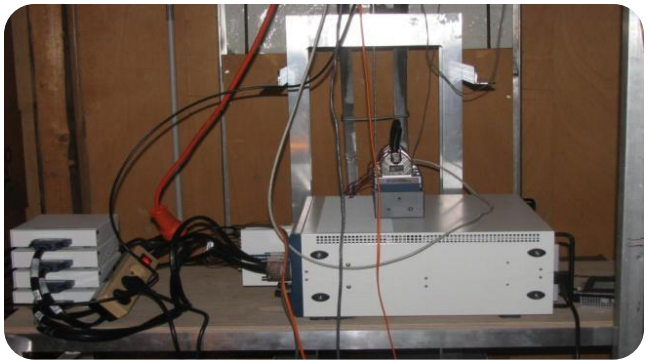
Fast and Thermal Neutron Testing



Frascati Neutron Generator, ENEA, Italy (**Fast**)

TRIGA Reactor, JSI, Slovenia (**Thermal**)





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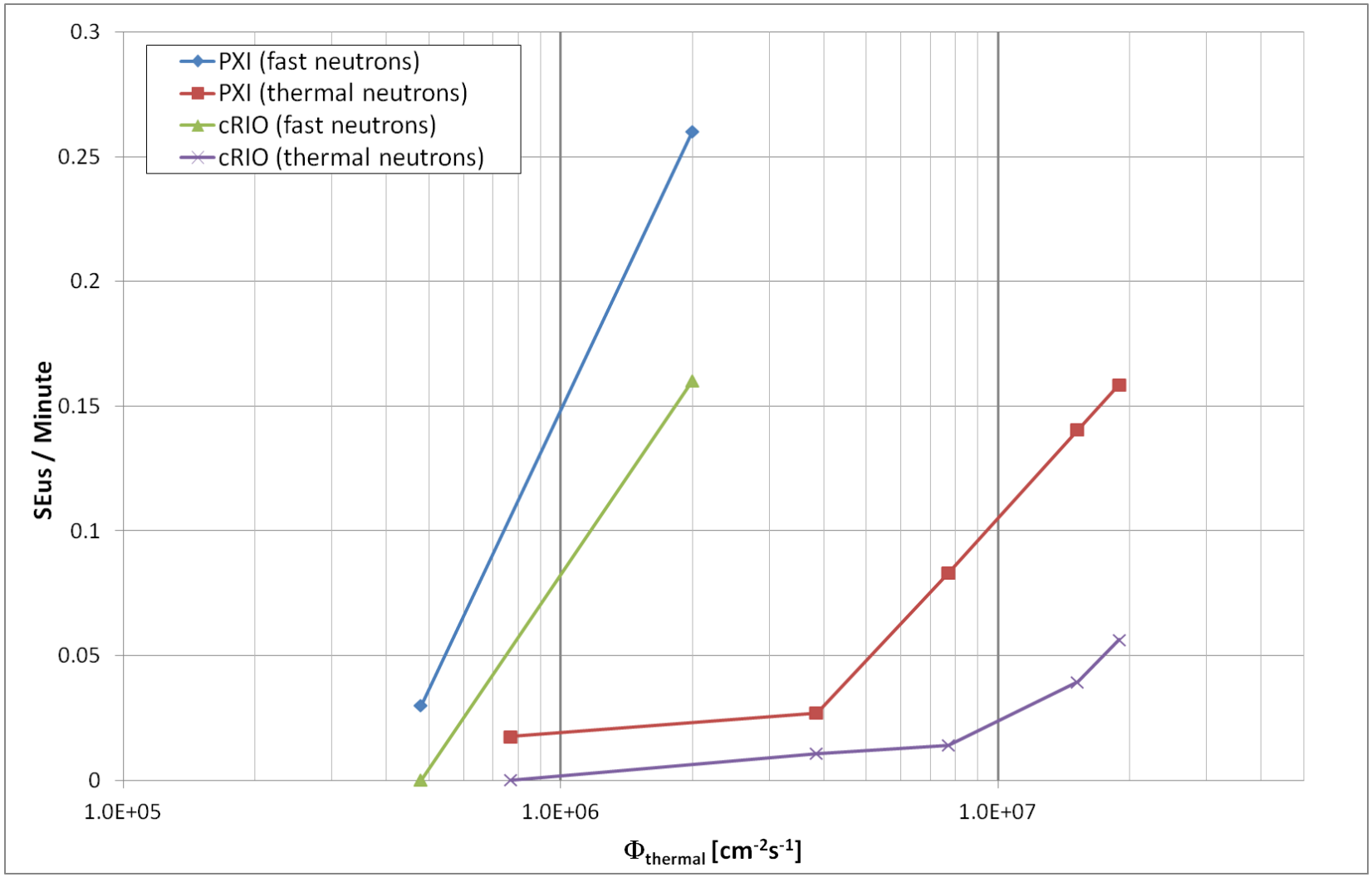
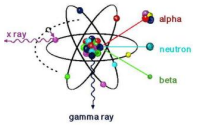
Failure Rate vs Neutron Flux



Radiation Testing Conclusions



- Gamma Testing
  - Most devices exceeded expected failure dose of 50Gy
  - Cumulative effects are evident in the gamma testing
- Fast Neutron Testing
  - Single Event Upsets dominated the neutron results generally meeting ITER requirements
  - Did not see permanent damage
- Thermal Neutron Testing
  - Almost 1 order of magnitude more flux compared to fast neutron
  - Failure rates were less than or equal to what was seen with fast neutron testing
  - MIO hardware handled thermal much better than fast (0 failures)

Magnetic Field Testing at DESY: Phase 1

PXI Chassis
- Fans fail between 15mT - 25 mT
- Investigation to find fans tolerant to higher field continues

NI 9148 (cRIO Ethernet Chassis)
- Chassis works well up to 60 mT
- Permanent HW damage at 230 mT

cRIO-9205 & cRIO-9263
- Works well up to 40 mT
- Data error between 40 and 50 mT
- Permanent HW failure after several minutes at 50 mT

Reliability, Availability, Serviceability, Maintainability

Big Physics Applications

RASM

EPICS Support

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Radiation and Magnetic Field Testing

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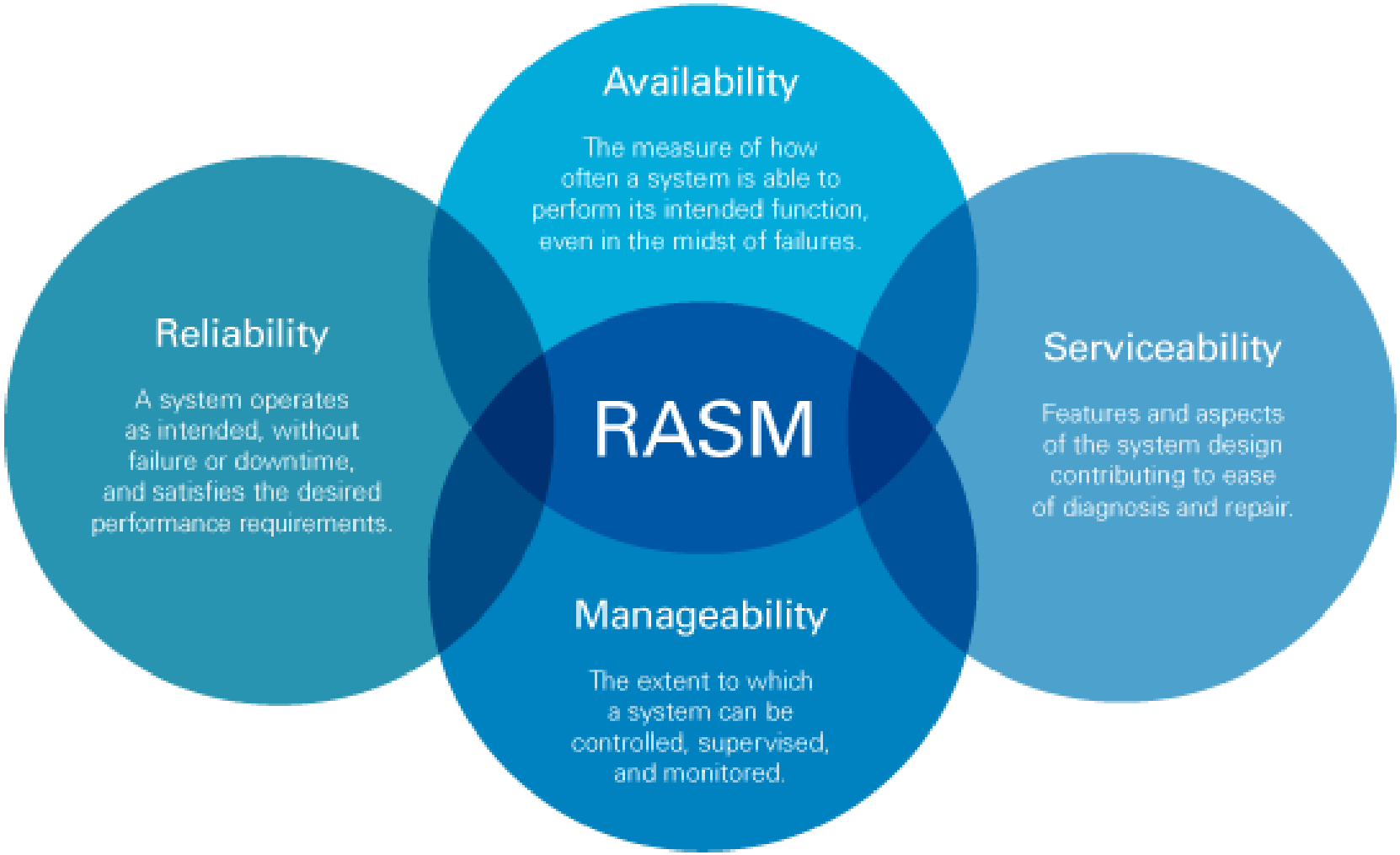

Availability
The measure of how often a system is able to perform its intended function, even in the midst of failures.
Reliability
A system operates as intended, without failure or downtime, and satisfies the desired performance requirements.
RASM
Serviceability
Features and aspects of the system design contributing to ease of diagnosis and repair.
Manageability
The extent to which a system can be controlled, supervised, and monitored.

System Reliability Lab (SRL)

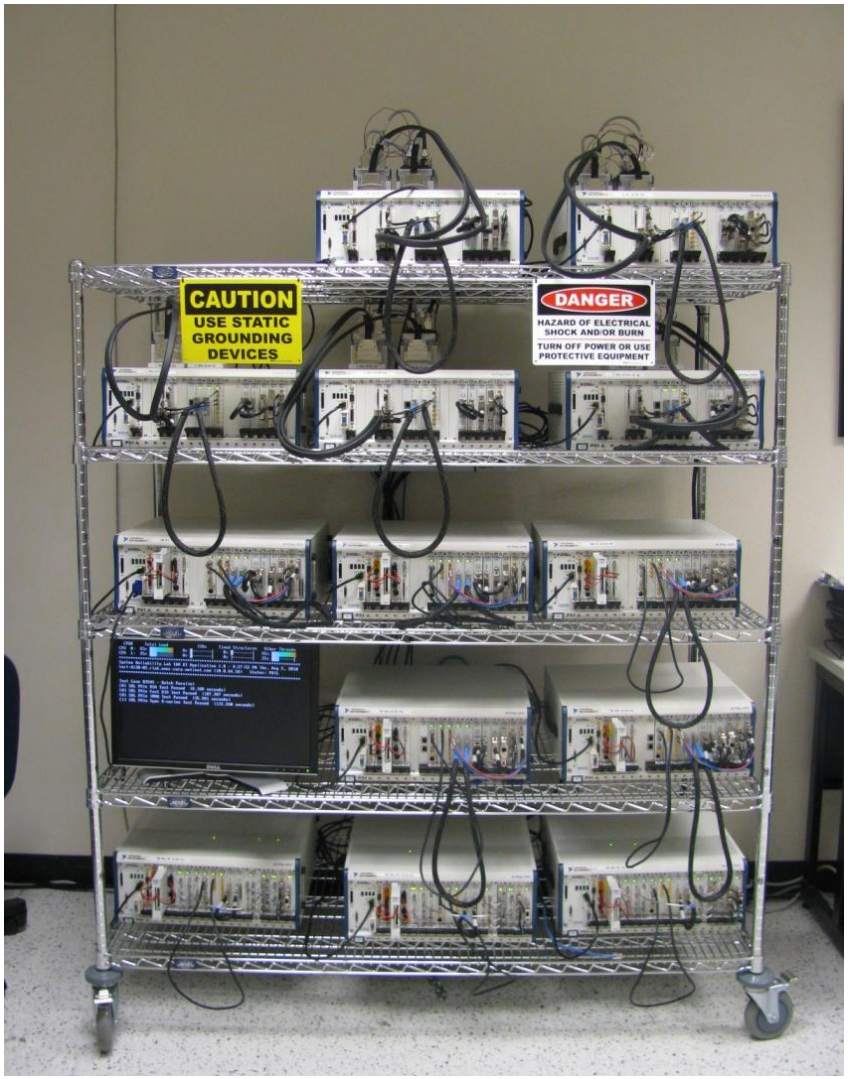
Mission:

Assess the reliability of National Instruments product-based systems and drive product improvements

- Created to focus on system reliability for the:
  - Compact RIO and PXI / PXIe hardware platforms
  - LabVIEW software platform

SRL PXI/PXIe Testing

- 20 systems
  - 18 systems at room temperature
  - 2 systems in temperature chamber (cycles between 5°C and 50°C)
  - 5 systems running on dirty power
- 3 different hardware configurations
- 32 test applications
- 24/7 execution during missions



SRL cRIO Testing

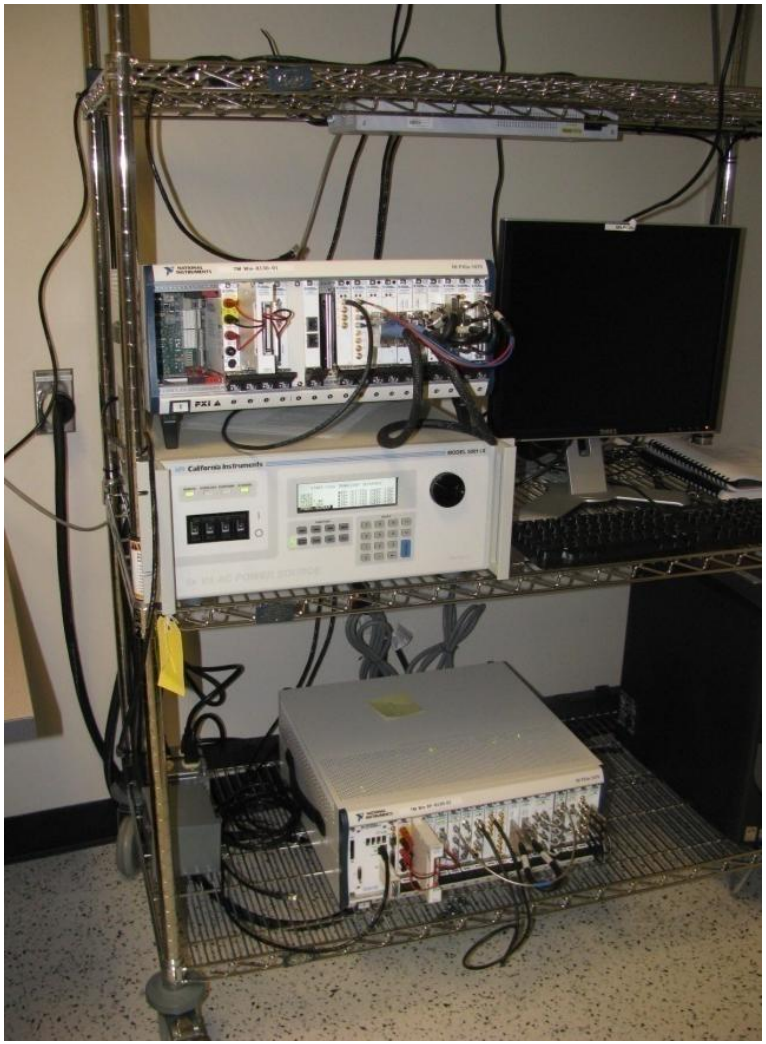
- 40 systems
  - 32 systems at room temperature
  - 8 systems in temperature chamber (cycles between -40 and 70°C three times per day)
  - 8 systems running on dirty power
- 4 unique cRIO applications
- 24/7 execution during mission

SRL Temperature Chamber

- Cycle Temperature three times per day for months
- 2 to 8 Systems run for months at time in this environment
- PXI / PXIe: 5°C to 50°C
- cRIO: - 40°C to 70°C

SRL Dirty Power Test Station

- Simulates a bad power grid
- 5 to 8 Systems run for months at time in this environment
- Vary frequency from 47 to 63 Hz
- Vary voltage level from 90 to 264 V



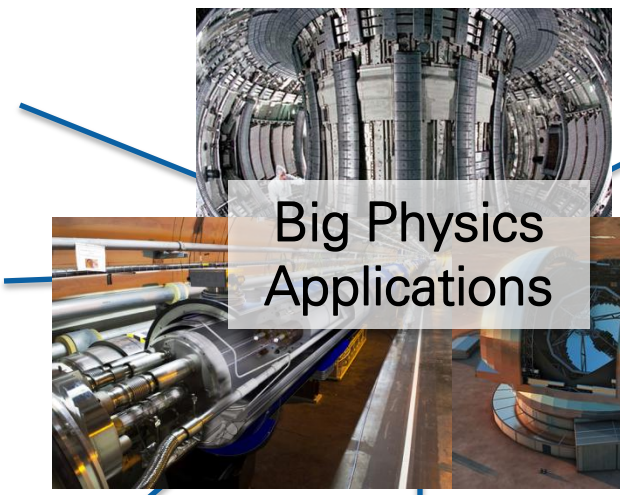
SRL MTBF Numbers

- **PXIe 8130 controllers** have over 40 years of run-time data and 1 failure = 40 yrs / 1 failure = **40 years per failure**
- **PXIe 1075 chassis** have over 40 years of run-time and 2 failures = 40 yrs / 2 failures = **20 years per failure**
- **cRIO 9014** controllers have over 76 years of run-time data and 2 failures = **38 years per failure**
- **cRIO 9104 chassis** have over 76 years of run-time and 0 failures **>76 years per failure**

CERN High Availability Chassis

- Redesigned to mechanically fit into a custom rack
- Independently powered, redundant hot swap power supplies and fans
- Remote Monitoring : Chassis Temperature, Fan Status, Power Supplies

Lifecycle Management



Linux Support

RASM

EPICS Support

Lifecycle Management

Radiation and Magnetic Field Testing

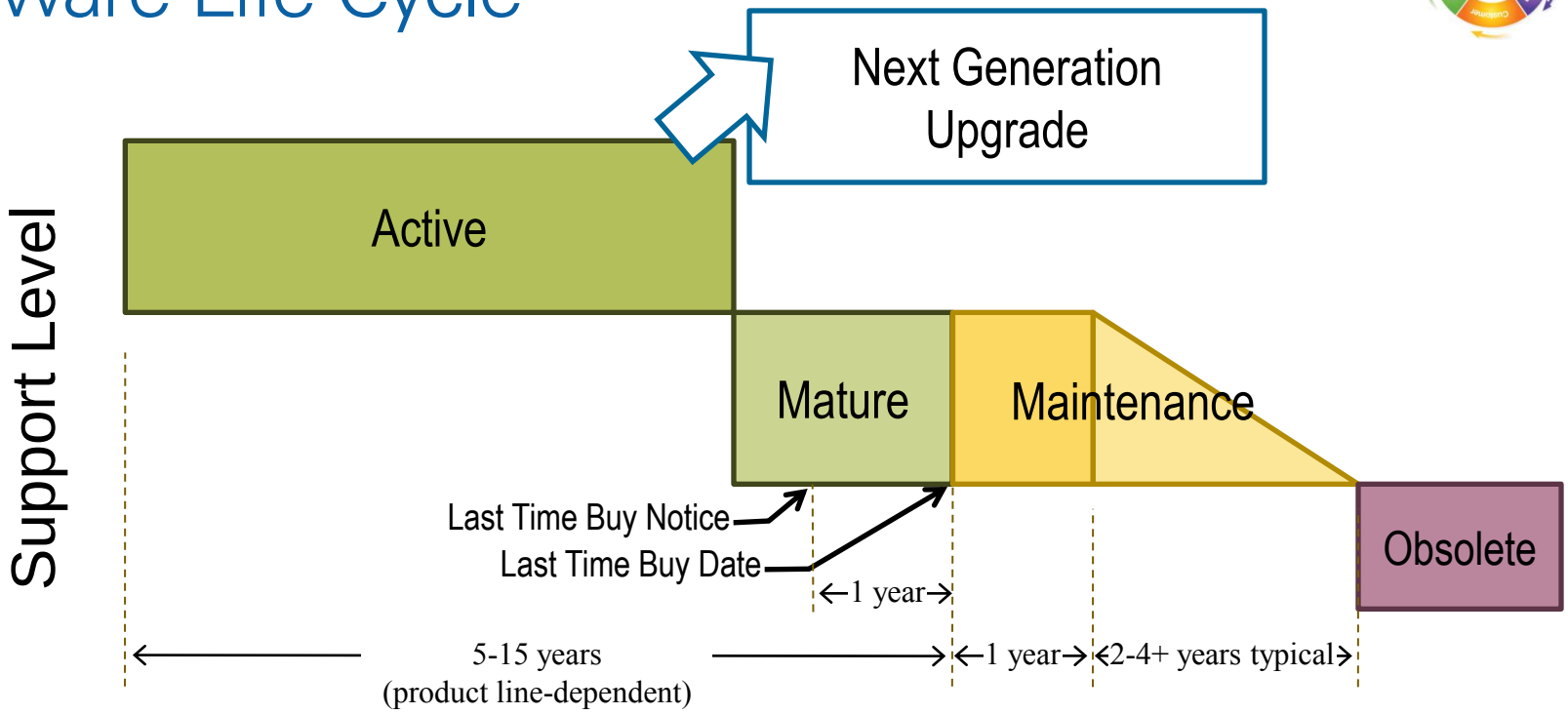
Safety : EMI, UL, CE, SIL

Environmental: ROHS, ChinaROHS, WEEE

Global Technical Support

Global Calibration And Repair

Hardware Life Cycle



	Active	Mature	Maintenance		Obsolete
Purchase new	Yes	Yes	No	No	No
Repair	Yes	Yes	Yes	Reasonable effort	No
Calibration	Yes	Yes	Yes	Reasonable effort	No
Service Agreements	Yes	Yes	Yes	Yes	Yes

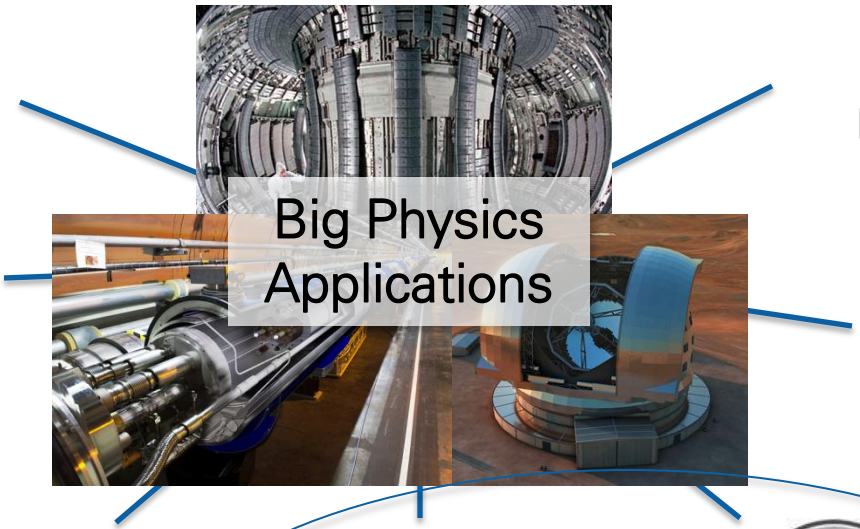
Lifecycle Planning

Product	Part Number	Released	Active	Mature	Maintenance	Obsolete
cRIO-9072	779998-01	Nov-2007	Nov 2007 - Nov 2012	Nov 2012 - Nov 2017	Nov 2017 - Nov 2022	Nov-2022
cRIO-9073	780471-01	Nov-2007	Nov 2007 - Nov 2012	Nov 2012 - Nov 2017	Nov 2017 - Nov 2022	Nov-2022
cRIO-9074	779999-01	Nov-2007	Nov 2007 - Nov 2012	Nov 2012 - Nov 2017	Nov 2017 - Nov 2022	Nov-2022
cRIO-9002	779000-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9004	779055-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9012	779563-01	Nov-2006	Nov 2006 - Nov 2011	Nov 2011 - Nov 2016	Nov 2016 - Nov 2021	Nov-2021
cRIO-9014	779564-01	May-2007	May 2007 - May 2012	May 2012 - May 2017	May 2017 - May 2022	May-2022
cRIO-9022	780718-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9023	781173-01	Feb-2010	Feb 2010 - Feb 2015	Feb 2015 - Feb 2020	Feb 2019 - Feb 2024	Feb-2024
cRIO-9024	781174-01	Aug-2009	Aug 2009 - Aug 2014	Aug 2014 - Aug 2019	Aug 2019 - Feb 2024	Feb-2024
cRIO-9025	781313-01	Jan-2010	Jan 2010 - Jan 2015	Jan 2015 - Jan 2020	Jan 2020 - Jan 2025	Jan-2025

Product	Part Number	Released	Active	Mature	Maintenance	Obsolete
cRIO-9101	779052-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9102	779007-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9103	779053-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9104	779054-01	Aug-2004	Aug 2004 - Aug 2010	Aug 2010 - Aug 2014	Aug 2014 - Aug 2019	Aug-2019
cRIO-9111	780915-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9112	780916-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9113	780917-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9114	780918-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9116	780919-01	Feb-2009	Feb 2009 - Feb 2014	Feb 2014 - Feb 2019	Feb 2019 - Feb 2024	Feb-2024
cRIO-9118	780920-01	Aug-2009	Aug 2009 - Aug 2014	Aug 2014 - Aug 2019	Aug 2019 - Feb 2024	Feb-2024

First 1/3 of phase
Second 1/3 of phase
Third 1/3 of phase

Global Services



Linux Support

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Lifecycle Management

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Global Technical Support

Global Calibration And Repair

Committed to Your Success

Technical sales engineers in more than 40 countries

Systems engineers to assist

Local technical support worldwide

Global manufacturing

World-class NI services

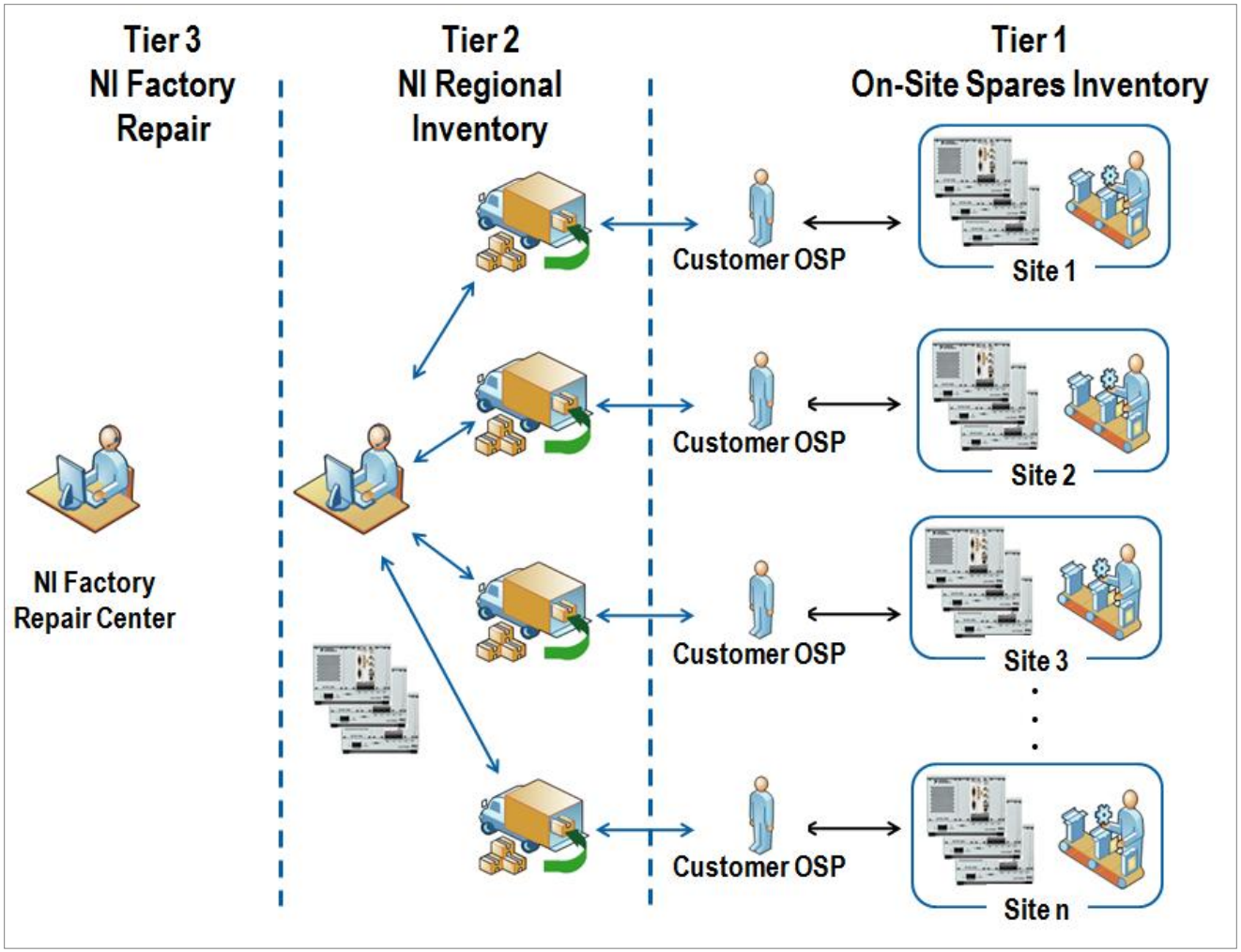
700+ NI Alliance Partners worldwide

Calibration Services

NI Flexible Calibration Options Reduce Maintenance Expenses

Perform verification and adjustment of NI products in your own metrology lab	Your existing service providers can verify and adjust NI products	NI can calibrate your device at the NI service center in your region	NI can provide calibration service at your facility
			
NI Calibration Executive	**Calibration Support**	**Regional Calibration**	**Onsite Calibration**

Global Sparing and Rapid Replacement for High Availability Requirements



Safety Certifications

Linux Support

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EPICS Support

Lifecycle Management

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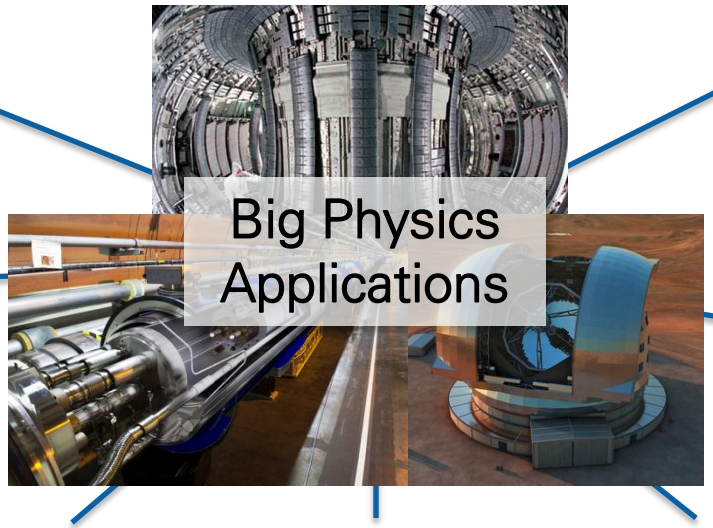

Environmental: ROHS, ChinaROHS, WEEE

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Global Calibration And Repair

Environmental Certifications

Linux Support

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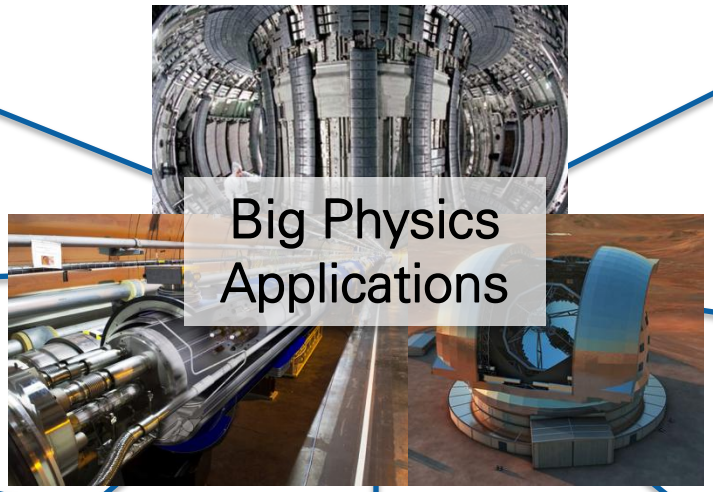

Safety : EMI, UL, CE, SIL

Environmental: ROHS, ChinaROHS, WEEE

Global Technical Support

Global Calibration And Repair

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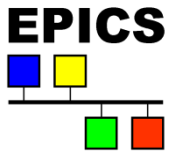
Summary

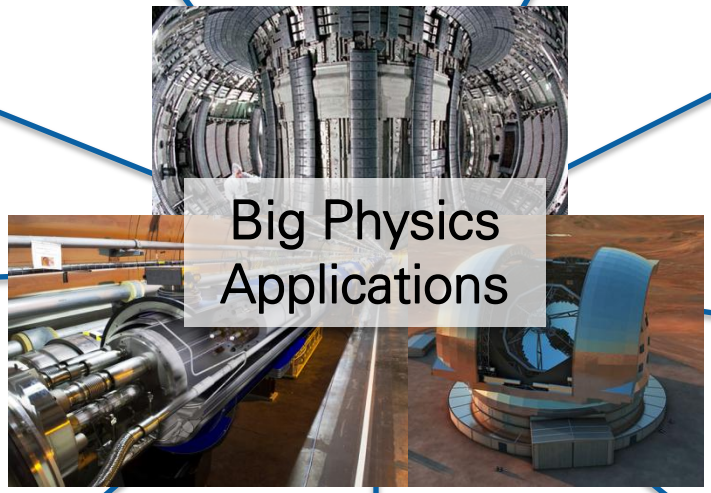
Linux Support

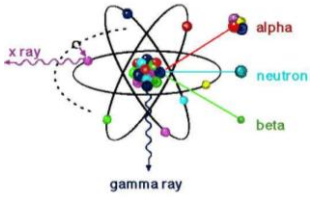
RASM



EPICS Support

Lifecycle Management





Radiation and Magnetic Field Testing

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Global Calibration And Repair

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